TEST EFFECTIVENESS TREND OBSERVATION

Assessment of EMI Grounding Problems Encountered in Flight Hardware Prior to System Level EMI Tests

CONCLUSION:

Because the vast majority of electromagnetic interference (EMI) grounding problems are detected by functional testing during hardware design and development, increased emphasis should be placed on: 1) the early implementation of EMC design guidelines for grounding techniques, and 2) development of EMI tests for detecting grounding problems at the assembly level as a check.

BACKGROUND: There are three major types of EMI grounding problems:

1. Common Impedance Coupling. The conventional notion of "ground" is as a zero-impedance, equipotential surface and often it is considered from the standpoint of its DC performance. Neither of these aspects are applicable to "ground with regard to its application in EMI. All conductors have certain amount of impedance at RF (most prevalent, inductive impedance); consequently, any currents that pass through that "ground" will cause points on its surface to be at different potentials due to voltage drops across the impedance. Hence, if several assemblies are connected to that "ground" at several locations, each assembly will be at different potential with respect to ground. This neonatal effect of ground impedance can be responsible for possible "crosstalk" between assemblies.

2. Unintentional Ground Paths. It is assumed that currents will return to their source via the paths intentionally provided for this purpose. At DC and low frequencies this is usually the case. However at radio frequencies (RF) and microwave (MW) frequencies it cannot be assumed that currents will return along the intended paths. If the current has spectral components that cover a wide frequency range, some of its frequency components will return along the intended ground plane, while other frequency components "of this very same current" will return along a different path. These unintentional ground paths originate from the effects of parasitic capacitive and inductive coupling among return paths. This non-ideal behavior of ground paths at higher frequencies is another cause for crosstalk among assemblies.

3. Ground Loops. It is frequently necessary to pass signals between two (or more) assemblies whose ground systems are intended to be distinct. The difference in voltage between two ground systems can result in potentially serious interference problems. The voltage difference between the two connection points (to ground) acts like a voltage source, and will drive common-mode currents through the signal and return paths between the two assemblies and between the two connection points. The "loop" completed by common-mode currents can also generate unintended radiated emissions. Even if one of the assemblies is not physically connected

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to a ground point, parasitic capacitance between the assembly and the ground system can effectively couple the circuit.

DISCUSSION:

EMI grounding problems were investigated for 9 spacecraft missions from the late 1960's to the present. Included were the Mariner-Mars(1969, 1971), Mariner-Venus, Seasat, Viking, Voyager, Galileo, Magellan, and Mars Observer spacecraft. The investigation was based on Problem/Failure Reports (PFRs) generated not only during EMC testing but during the developmental phases of each of the projects. Table 1 describes preliminary results of this investigation. For each of the 9 projects outlined in Table 1 (Column 1) a comparison is established between the total number of PFRs related to EMI tests (column 2), and the number of PFRs generated as a result of EMI grounding problems (Column 3). Column 4 in the table shows the percentage (%) of PFRs from Column 3 which are related to: a) ground loops, and b) noise coupling through unintentional ground paths. Ground loops and noise coupling (through ground) were the two major sources of EMI due to grounding.

In summary, the investigation revealed the following:

1. EMI ground problems constitute one of the largest contributors of EMI related PFRs on all spacecraft. The number of PFRs generated by EMI ground problems is considerably large when compared with all other EMI-generated PFRs.

2. the large majority of all EMI ground problems were identified during the design and developmental phases of spacecraft assemblies.

3. EMI ground problems are unlikely to be identified during system level EMI tests.

4. a predominant grounding EMI problem consisted in the presence of ground loops and noise coupling via grounds, and

5. there is a need to develop and apply improved grounding and EMI guidelines early in the design process. Furthermore, there is a need to develop EMI testing methods for detecting EMI grounding problems during assembly level development.

Most EMI problems related to grounding usually surface during functional testing at the assembly level prior to EMC testing. There are several reasons for such a trend:

1. Most grounding problems are very disruptive by nature (i.e the assembly does not perform its functions or performs them with severe degradation). Hence, they are immediately corrected before the assemblies are subjected to environmental testing or integrated as part of a system;

2. Most EMC-tests are performed at the system level where very few system-level grounding problems are detected. There are no explicit EMC-tests for detecting grounding problems at the system level (except for the isolation-test which guarantees that the equipment under test is DC-grounded before other EMI-tests are performed); and

3. There is a lack of understanding among design engineers concerning RF grounding guidelines, methodologies for avoiding RF grounding problems, and analysis of RF grounding paths.

System level grounding problems may result from RF noise coupling during radiated and conducted susceptibility tests but they are unlikely to be distinguished from other EMI problems (e.g field-to-cable EMI, close coupling EMI) due to the lack of adequate test methods for detecting RF grounding problems.

Table 1. Comparison of PFRs Due to EMI Grounding Problems with Total Number of EMI PFRs From EMC Tests

PROJECTS	No. of EMI PFRs Obtained from EMC-Tests	No. of EMI PFRs from Grounding Problems NOT Recorded in EMC-Tests	"Ground Loops" & "Noise Coupling" EMI PFRs from Grounding Problems	
			No.	%
Seasat	2	0	0	0
Mariner-Mars (1969)	11	10	4	40
Mariner-Mars (1971)	5	27	13	48
Mariner-Venus	2	8	4	50
Mars Observer	24	16	4	25
Magellan	18	3	1	33
Galileo	43	13	7	54
Voyager	68	21	10	47
Viking	44	12	9	75

[*] Tests were sparse and only on system level